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BOSTON AIR ROUTE TRAFFIC CONTROL CENTER (ARTCC) LIGHTING STUDY,

(10)

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Richard L. Sulzer
Alan J. Kopala

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16. Abstract

The purpose of this project was to facilitate the viewing of flight data on plan view displays (PVD's) and the reading of other pertinent data in the ARTCC control room by air traffic controllers. This was accomplished by attenuating distracting light and reflections on the PVD face and increasing the ambient room lighting level. In implementing these objectives, the work consisted of modifying various parts of air traffic control (ATC) equipment in the assigned test area D of the control room. The lighting modifications were evaluated technically by Raytheon and were appraised by a survey, conducted by NAFEC, of the air traffic controllers. The package of modifications was well received by the controllers, but they considered it inadequate and desired more effective improvements. The results of the study indicate that discrete lighting modifications only partially solve the reflection/lighting problem.

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METRIC CONVERSION FACTORS

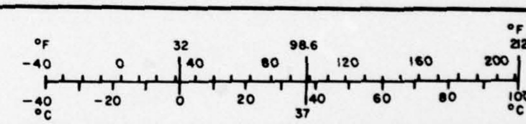
Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.

Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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PREFACE

Appreciation is hereby expressed to the personnel of the Boston Air Route Traffic Control Center for their cooperation in the technical evaluation of lighting modifications and their participation in the survey for the human factors study.

Much gratitude is conveyed to Dr. Richard M. Carr and Mr. Charles M. Hall of Raytheon Company for their outstanding work and significant contributions towards the lighting study program.

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INTRODUCTION

PURPOSE.

The purpose of the Boston Air Route Traffic Control Center (ARTCC) Lighting Study was to improve the air traffic controllers' visual tasks by reducing the front-surface reflections on the plan view display (PVD) face, and by increasing the ambient lighting in the control room. These objectives were intended to satisfy the observations of air traffic controllers that the light reflections interfered with their constant monitoring of displayed flight data and that the control room environment was too dark to read pertinent work memoranda.

AUTHORIZATION OF RESPONSIBILITIES.

This program was initiated in response to a formal request by Air Traffic Service, AAT-100, to Systems Research and Development Service (SRDS), ARD-100. Reference should be made to Federal Aviation Administration (FAA) form 9550, No. AAT-100-34, "ARTCC Control Room Lighting." The Lighting Study was conducted in test area D of the Boston ARTCC and coordinated with the New England Regional Office, under Inter-Agency Agreement No. ARD/ANE-76-207.

The National Aviation Facilities Experimental Center (NAFEC) was responsible for the project management of the lighting study.

Raytheon Company, under contract number DOT-FA76WA-3738, was charged with identifying reflection sources, recommending practical solutions, and evaluating prescribed modifications by photometric measurements. To document their work, Raytheon published a final report entitled, "Air Route Traffic Control Center Lighting Study," (reference 1). Manpower for on-site hardware installation and program coordination was provided by personnel of the Boston ARTCC and the New England Regional Office.

BACKGROUND.

The conversion of the PVD to the near vertical position at ARTCC's has resulted in a marked increase in specular reflections from opposing display surfaces, walls, and ceiling that illuminate the faces of the displays. Prior to the introduction of digital narrowband radar, the PVD presented only broadband radar and was positioned at 6° from horizontal. When in this position, the specular reflection problem was not significant.

Since the viewing surface of the PVD's has been set at 68° from the horizontal position, complaints have been raised by controllers about the specular reflections. The first attempt to solve the problem consisted of turning off both the direct overhead lights and the indirect lights located in the the plenums behind the consoles. This succeeded in eliminating the specular reflections emanating from the walls and ceiling, but caused four other, more serious

problems. First, extinguishing of the overhead lighting failed to eliminate the specular reflections originating from light sources on the other side of the aisle, e.g., map boards, flight strips, printer lamps, etc. Second, since the control room was darkened considerably, it became difficult to walk down the aisle and to read or write at any position but the "A" or "D" controller positions. Third, the difference in illumination level between the relatively dark PVD face and the bright, front-lighted flight strips has led to complaints of eye fatigue, as the radar controllers must look back and forth between the PVD and the flight strips. Fourth, the decreased illumination revealed a new problem of distracting glare sources from the supervisor's desk, speaker bezels, printers, and flight strip bays.

Preliminary investigations of this problem were undertaken at NAFEC, and potential improvements were identified (reference 2). These investigations could not be carried out further at NAFEC because of differences between the NAFEC environment and the standard ARTCC environment (lower ceiling height, noncarpeted floors, etc.). Therefore, the evaluation of potential improvements was conducted at the Boston ARTCC.

DISCUSSION

GENERAL.

The work of the lighting study was conducted in two parts, labeled phase I and phase II, in test area D of the Boston ARTCC control room. During phase I, sources of the lighting/reflection dilemma were identified and investigated, resulting in the experimental lighting modifications of the air traffic control (ATC) equipment. Phase II consisted of applying the most practical and efficient phase I modifications to all of the sectors in area D, and of conservatively estimating the effectiveness if applied to the entire room. In both phases, test and evaluation methods were kept parallel to ensure the comparative integrity of the two sets of lighting data.

Area D of the control room was chosen as a test bed because it was in use for active sectors by controllers which would provide an opportunity for truly dynamic, real-time testing. It occupies one-fourth of the control room and comprises the ATC equipment and working environment of sectors 1 through 6 in row 1, and sectors 15 through 20 in row 2. The location is in the right-rear quadrant with reference to the watch supervisory complex.

EVALUATION CRITERIA.

Raytheon lighting experts performed photometric measurements of the glare/reflection sources during the lighting study. They measured reflected light with a Gamma Scientific Model 2000 telephotometer and took direct readings of ambient light intensity with a Gossen Lunasix light meter. The test points were located at various distances from the ambient illumination sources and also from the mapboards, flight strips, printer, PVD console, and from

the PVD glass front surface--the most important of all the measurement locations. A complete description and tabulation of the phase I lighting measurements can be found in the Raytheon Report, sections 5.4 and 6.1, in reference No. 1.

To quantify the benefits of the lighting study modifications to daily air traffic control (ATC) work, NAFEC human factors personnel surveyed the controllers' opinions of the changes. In each of the human factors studies of phases I and II, NAFEC prepared questionnaires to provide those necessary data and administered them to the air traffic controllers and supervisors of test area D. The results of the phase I survey indicated a general belief that the specular reflections on the PVD and the glare sources had been reduced by the control room modifications. However, a need was still conveyed by the controllers for increased ambient illumination in the control room and for more glare and reflection reduction. This feedback precipitated phase II of the Boston ARTCC Lighting Study--the extension of the best phase I modifications and new modifications to the entire test area D.

WORK DESCRIPTION.

The types of control room equipment that were experimently modified were the overhead mapboards, flight strip lighting and printer, the PVD, area supervisor's desk, and the ambient room lighting. These modifications involved attenuating annoying glare sources from various points on the equipment, reducing the light reflections that interfere with the controller's observation of PVD flight data, and providing adequate illumination from ambient lighting and work lamps in area D. The modifications were not complicated in nature and did not hinder the controllers in their daily work. They consisted of some electrical, and mostly mechanical, retrofits to the ATC equipment. Described in the following sections are the major areas of modification in test area D during phase I and phase II of the Boston ARTCC Lighting Study. For more information on the modifications, reference should be made to the Raytheon "ARTCC Lighting Study Report", (reference 1). This reference amply describes all phase I work and illustrates the subject problems, glare and reflections.

MAPBOARDS. During phase I, three methods were tried to eliminate mapboard reflections on the PVD face and yet provide adequate visibility of the maps to controllers. The methods consisted of time-delayed lighting, black negative maps, and 3M Company light control film.

The first method involved the installation of an adjustable, time-delayed switch to the mapboard lamp. This timer switch, activated by a pushbutton installed on the console, allowed the controller to illuminate his overhead map at will and thus would minimize the time of the mapboard reflection in the opposite PVD. After a preset time, the map light would extinguish automatically.

The second method used black negative maps made from DuPont Crolux® film. Each was essentially a photonegative image (i.e., transparent alphanumerics/ lines on a black background) of the previous maps. When they were illuminated

from the back, the black portion eliminated light emission which prevented opposite PVD mapboard reflections and legibly displayed information on the black map through the film's transparent areas.

The third method used 3M light control material to form a selective viewing angle of the overhead map for the controller. This film blocked extraneous light outside of this viewing angle, thus preventing it from reflecting onto the opposite PVD. This material, taped in two pieces to the inside of the mapboard windows, was a plastic sheet that had an internal structure similar to "venetian blind" louvers and was supplied with a specified viewing angle.

The light control material was the best of the three techniques in reducing the mapboard light output incident to the PVD face on the opposite side of the aisle. The photometric measurements and human factors study of phase I confirmed this claim. The black negative maps reduced extraneous light output compared to the conventional clear map, but could still be noticed as a reflection on the opposite PVD face. Also, the black maps were relatively expensive and became increasingly self-defeating as more information was displayed, because more white and less black area would result and cause the black map to emit increased light. Most controllers rejected the time switch because of the need to push another button. Complaints were made on the time delay being too short for map readings, and on the nuisance of locating the pushbutton during busy, critical times in ATC work.

During phase II, the black maps or the 3M material were applied to all sectors in test area D and retested. This second test not only provided more data to determine the better method, but simulated the overall effects of a control room devoid of conventional bright mapboards. The majority of the controllers again preferred the 3M light control material on the mapboards, and rejected the black maps on second trial.

FLIGHT STRIPS. The flight strips at the console "D" positions were subject to investigation during the lighting study because of light spillage from the flight strip lamps onto the PVD as reflections, and the annoying contrast between the viewing of the dark PVD area and the bright glare of the flight strip columns illuminated by overhead lamps. The methods used during phase I, in limiting flight strip lighting, were the separate attachments of a 1/2-inch black directive louver assembly, commonly called "egg crating," and a combination of this same louver assembly and 3M material. The 3M material was identical to that used on the mapboards (see MAPBOARD section).

The 1/2-inch louver assembly, without the 3M material, performed poorly in directing light flow solely to the flight strips and needed replacement by a better method. A 36-inch strip of 3M light control material was placed between it and the flight strip lamps. This combination markedly improved the directioning of the illumination, but necessitated the removal of 12 inches of the right-hand side of the 3M material to regain the visibility of the flight strips for the controller at the "A" position. However, the controllers and lighting experts were not satisfied with the results, since the flight strip lighting was considerably attenuated by the 3M material; therefore, a better method was sought, and found, in phase II.

In phase II of the lighting study a louver assembly having much longer fins was installed for test in every "D" position of area D. The 3M material was omitted because of its excessive light-attenuating characteristic. The new louver assembly was far superior in controlling light spreading to the PVD face, while not reducing the effective illumination on the flight progress strips nearly as much as had the light control material film used in phase I.

Also added to the flight strip lighting during phase II was the substitution for the original equipment lamps in all "D" positions by Luxor Vita-Lite® lamps. These fluorescent bulbs have an output light spectrum that closely resembles natural outdoor daylight. Photometric tests revealed that they improved the brightness and contrast of the first row of flight strips, thus making the flight strips easier to read. There were many good opinions on the Luxor lamps, and they were also tested for the plenum lights, as discussed in the AMBIENT LIGHTING section.

FLIGHT STRIP PRINTER. Two sources of glare disturbing to the controllers were the brightly lit paper on the flight strip printer and its "Ready" and "First Line" indicators. This problem was studied in phase I, and three types of modifications to attenuate these light levels were tested: gray filters, green filters, and 3M light diffusing film (different from and not to be confused with 3M light control material).

To lower the paper glare, filters were fitted over the paper-illuminating lamp inside the printer. Gray filters were fitted to some, and green filters were fitted to others. The evaluation of these modifications during phase I strongly favored employment of the green type of filter. The green filter underwent further testing in phase II to determine the final opinion of it when implemented throughout all of test area D.

In phase I, green filters, gray filters, and 3M diffusing tape were applied to the printer indicators. These were tested, and when evaluated, were ranked in acceptance by the controllers in the same order. Although the 3M diffusing film was inexpensive in cost of material and installation, especially when compared to the gray and green filters, it finished last of all three in light attenuation and therefore did not merit further testing.

Green filters were applied to all printers in area D during phase II, and the results of the evaluation again showed a strong preference towards them in their ability in reducing the glare.

PLAN VIEW DISPLAY. Two areas of concern on the PVD were the keycaps and the cathode ray tube (CRT) face, the latter being the most important of all areas, since it is the location of the distracting reflections. During phase I, an investigation was made into reducing the glare from the keycaps and into direct modifications relating to the CRT face itself to minimize reflections.

The keycaps were modified by replacing their original legends with new ones made from photonegative film. The new photonegative keycap appeared as the

inverse of the original keycap, having a black background with transparent lettering. The lamp behind the "white on black" keycap emitted light only through the alphanumeric legend; thus, annoying glare was significantly reduced and legibility was increased. This sample, an inexpensive improvement, was well received by the controllers during phase I, and was well received again in phase II when the negative keycaps were implemented in all sectors of test area D.

Certain modifications to the PVD face were performed during phase II. One consisted of a tilt device fabricated by NAFEC. When installed in the PVD, it provided an adjustment of its inclination angle from 6 to 68° with respect to the horizontal. The purpose of this feature was to provide a viewing angle that would minimize reflections on the PVD face. The evaluation of the controllers' opinions, in phase II, revealed a general dislike for this modification, since the reflections were not significantly reduced, regardless of angle, and the modified PVD was difficult to maneuver when the need arose.

The second modification involved the use of a woven screening material. It consisted of a black polyester mesh cloth named PeCap® manufactured by Tetko, Incorporated. It was mounted on the face of one PVD in area D to determine its ability to disperse light reflections without degrading the resolution of displayed ATC information. After the controllers had observed the woven screening on the PVD face, the general consensus was that of disapproval.

Although it did decrease reflection, the screening had a very low light passage characteristic, and therefore required the CRT intensity to be set at a very high level which would eventually lower CRT life. Also, the woven screening was difficult to mount on the surface of the PVD face without creasing the material, and, unlike the present CRT surfaces, it could not be marked with a grease pencil for indicating important ATC points on the display.

<u>SUPERVISOR'S DESK</u>. The supervisor's desk of area D was investigated during phase I because its desk lamp and glass writing surface caused annoying glare and reflections on nearby PVD's. A light baffle for the desk and a new, highly directional desk lamp were recommended by the lighting study team.

The baffle was 12 inches high, black, and surrounded the three sides of the desk opposite the supervisor's side. This greatly restricted light flow from the desk surface and shielded desk light from the controllers at nearby consoles. The evaluation of the baffle showed general approval, and no further testing was planned for phase II of the lighting study.

Raytheon arranged for five different lamps to be evaluated, all with deep shades for limiting light to the desk work area. The lamps were tested by the supervisors at their desks at all of the four control room areas, A through D, plus at a desk in the rear of the control room. The human factors survey revealed that both the supervisors and the controllers strongly preferred the Tensor Model 6500 and the Luxor Student Crownlight lamps. Raytheon lighting personnel studied both lamps and recommended the Luxor lamp because it had a longer, more versatile arm and used a readily available incandescent bulb instead of the 12-volt "auto" type bulb used in the Tensor model.

No further lamp evaluation was conducted in phase II. For details on the types of lamps evaluated see section 5.2.6, paragraph 2 of the Raytheon report (reference 1).

AMBIENT LIGHTING. In addition to the PVD front-surface reflections encountered by the controllers, the other primary concern of the Boston ARTCC Lighting Study was the ambient lighting in the control room. The problem is coping with a dark environment, which exists in order to minimize the annoying PVD reflections that would be aggravated by a comparatively bright "office room" type of lighting. This inadequate illumination has made it difficult to read written material in the aisle area. Ways to improve the ambient lighting without interferring with PVD observation were sought during the phase I investigation in test area D. In phase I, ambient lighting modifications that were implemented and tested were dimmer controls for balancing the plenum lights and under-the-shelf lamp fixtures.

A dimmer control was installed in each of the two console rows in area D to provide continuous adjustment of the plenum lights located on the top of the M1 consoles. The Raytheon lighting personnel determined an optimal setting of these controls that increased the ambient illumination without grossly affecting the PVD with light reflections. The human factors study indicated that the dimmer control modification was a significant improvement over the previous ambient lighting, but the reflection increases were objectionable.

To illuminate the floor walking area, fluorescent lamp fixtures were installed underneath the writing shelf of several consoles. Although the location of the fixture was planned with respect to safety, some controllers objected to these lamps on the grounds that they were hazardous to one's legs when seated at the console. Therefore, this modification was abandoned. Also it appeared that most of the light was limited to the immediate floor area in front of the console. The aisle received little added light.

During phase II of the Lighting Study, the ambient lighting was improved by the introduction of Luxor Vita-Lite fluorescent lamps in the plenum fixtures of test area D. These bulbs have an output light spectrum that most closely resembles natural outdoor daylight. These lamps did not drastically increase the ambient lighting level without causing PVD reflections, but they did improve the visibility of reading material in the work area coupled with the increased lighting level provided by the dimmer modification. The Luxor lamps were well received by most of the controllers in area D.

RESULTS.

In essence, the lighting problem in the ARTCC control room is a general one, found in a variety of situations in which people must read computer-generated transilluminated displays (i.e., CRT's at the PVD and D positions) while also making frequent reference to floodlighted paper materials such as flight strips, weather sequences, and typed notices. A further complication in ARTCC's is the requirement to display large-area overhead mapboards. Given this situation (the need to attend a CRT closely and still switch back and forth to papers), it is clear that glare and reflections will always be present, to some degree. If the room is well lighted there will be an overall veiling luminance

reflected from the front surface of all shiny or mirror-like substances, such as the glass cover of the main CRT. The controller's body blocks part of this overall light, causing a dark silhouette to appear. If a white shirt is worn or there are other reflective areas in the room, this silhouette will be detailed with lighter areas. In addition, light sources opposite the reflective surface, such as flight strip printer lights, communication channel lights, or bright mapboards will cause bright spots on areas of reflected light brighter than the overall luminance from the room walls and ceiling. Light spill from areas of floodlighting, such as the D console, also spreads across the PVD glass cover.

The problem caused by this situation is threefold. First, the majority of control room personnel want to work in a lighted room. This is because they must read various materials and because a well lighted environment is preferred. Second, reflections on the PVD are distracting. The controller must exert effort to disregard detail and movement on the front surface and concentrate on the data displayed on the phosphor layer of the CRT. Third, switching attention back and forth between the CRT and the more brightly lighted flight strips is an annoying nuisance to the controller.

The attempts made toward a solution of the control room lighting problem have been aimed at these three facets of the problem. With the balance control on the indirect or plenum lamps, the ambient illumination was increased in the test area. Each such increase has, however, increased front-surface veiling luminance at the PVD's.

To reduce bright reflections at the PVD, filters were tested on printer lights and a new light control material was applied on the overhead mapboards. Both have demonstrated capability to reduce "hotspots" on opposite row PVD's.

To improve flight strip lighting, a different type of fluorescent lamp, the Vita-Lite Luxor bulb, was tested and found to make flight strips more legible to both R and D men. To reduce spill from their lamps to the PVD's, the louvers were extended under the lamps. Since a hazard was presented by the louvered edges, a plastic cover was applied. Unfortunately, this cover was overdesigned and resulted in deflecting an excessive part of the light intended to fall on the flight progress strips. This could be corrected. Overall, the extended louvers did accomplish the reduction of light spill toward the PVD. At this time, we do not have a remedy for the contrast between the well lighted flight progress strips and the darker transilluminated CRT fields. Since flight progress strips must be legible to all control personnel, this means that they must be much brighter than the luminance presented by the PVD.

Questionnaire ratings by the Boston ARTCC personnel indicated general acceptance of the value of the following changes in lighting. The black background keycaps at the PVD and light-reducing green filters on the flight printer strips were well endorsed. Improved flight strip lights (Luxor bulb and extended louvers), mapboards with light-directing filters, and a shield around the aisle supervisor's desk were approved. One test item, the black

background negative map, was rejected. In the first test series, a time switch that shut off mapboard lighting after a variable period was rejected by the controllers. Also an attempt to increase aisle lighting and general room lighting by installing undershelf lamps on the control consoles was not approved. It should be noted that the addition of light control film at the overhead mapboards increases aisle lighting through the effect of directing light downward, toward the floor, rather than out and across to the opposite row of consoles. Controller judgments also indicated a lack of satisfaction with reflections at the PVD (partly caused by increased room light levels) and with the low aisle light level. Major improvements here apparently must wait for progress in treating the PVD surface to reduce reflections.

The Boston control room personnel do not believe that the total package of lighting changes constitutes a full remedy or a solution ready for national implementation. They want to see further increases in overall control room light levels, without the penalty of increased PVD reflections, and they want a reduction in the apparent strain caused by switching back and forth between the PVD and flight strips. At this time, it is not possible to promise attainment of these goals. As to strain, due to reference to both CRT and flight strip data, this may be inherent in the job as presently defined. Replacement of front-lighted flight strips with a transilluminated electronic tabular display may be one practical answer.

The controller questionnaires used in phases I and II are reprinted with summary tallies of answers in the appendix.

CONCLUSIONS

It is concluded that:

1. In the Boston ARTCC Lighting Study, potential sources of glare and reflections in test area D of the control room have been identified, and modifications have been devised and implemented to reduce these annoyances. These sources have been decreased in magnitude, but have not been completely eliminated.

2. The ambient lighting in test area D has been significantly increased, but cannot be raised to a normal room lighting level because this will drastically increase the reflections on the PVD's. This constraint necessitates the development of a new cathode-ray tube with an antireflective viewing surface that will permit a much brighter working environment.

RECOMMENDATIONS

It is recommended that:

1. The following AARTCC control room modifications should be implemented in the field:

EQUIPMENT	MODIFICATION	MATERIALS COST
1. Mapboard (each)	3M light control material	$50.00
2. Flight strip lights (each "D" position)	Extended louver with guard (deep-fin "egg crating")	$30.00
3. Flight strip printer (each)	Green filter	$25.00
4. Supervisor's desk (each)	Lamp and three-sided baffle	$40.00
5. Plenum lights (each)	Dimmer control	$69.00
6. Keycaps (per PVD)	White on black legends	$ 5.00

2. Major emphasis should be placed on the development of a new cathode-ray tube with an antireflective viewing surface.

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2. Gustafson, P. C., Aschenbach, J. A., and Sulzer, R. L., Plan View Display (PVD) Background Lighting, U.S. Department of Transportation, Federal Aviation Administration, Washington, D.C., Report No. FAA-RD-76-46, May 1976.

QUESTIONNAIRE

CONTROL ROOM LIGHTING IMPROVEMENTS

(Phase I)

INSTRUCTIONS

This questionnaire is intended primarily for qualified radar and manual controllers who have worked at the Boston ARTCC for at least one year. Please read and answer the questionnaire after making a thorough examination of the lighting changes in Area D and after sitting in the several control positions in this area and in another area with conventional lighting. If feasible, fill in your answers while still in the control room so that you may look back and see the several positions referred to in the questions.

NAME_______________ Years at this Center_______

DATE_______________ Usual AREA assignment_______

ATC Qualification: RADAR_____, MANUAL_____, ASST_____

If a supervisor, check here_______

INTRODUCTION

The goal in control room lighting improvement is to enhance the comfort and seeing efficiency of all personnel. Three factors can reduce seeing comfort and effectiveness: glare, stray light, and reflections.

Glare results from light sources that are too bright and are in your field of view because they are near things you need to look toward. If forced to look toward bright light sources while working with dim displays, the pupil of your eye must contract. This makes for fatigue, and it makes it harder to see dim targets and characters.

Stray light is light that falls on things that need not be illuminated, for example the controller's white shirt. Surfaces lighted by stray light may in turn become sources of reflections.

Reflections are unwanted images resulting from miscellaneous light sources and appearing on the surface of the PVD and other glass or polished surfaces. Since reflections are distracting and make it harder to see the important information, the main focus of the present lighting improvements aims to control glare and stray light so as to lessen the sources of reflections.

PRESENT IMPROVEMENTS

The changes that you are evaluating have been designed to lower the sources of general room lighting (to reduce stray light), also to reduce the intensity of glare sources (such as the printer lamps), and to further reduce annoying reflections by screening strip bay lights and key board lights to cut out scattered light.

NEXT STEPS

Please answer the following questions to indicate the degree to which you approve of the lighting changes and to give advice on any added improvements that you can recommend. Based on your answers and the results of light level measurements that are being made, changes in control room lighting may be recommended for national implementation.

1. **Check (X) aspects of control room lighting that you think have needed improvement before the current changes to make the job of the radar controller more comfortable and efficient.**

	Have Been Satisfactory	Needed Improvement
a. Reflections in PVD	1	28
b. Glare Sources (such as printer lamps)	5	25
c. Stray light (as from flight strips)	7	22
d. Overall aisle lighting	2	29

2. **Indicate whether you feel that the changes in the test area have brought about worthwhile improvement.**

	Have Been Improved	No Significant Improvement
a. Reflections in PVD	24	7
b. Glare Sources	21	10
c. Stray light	22	8
d. Overall Aisle lighting	17	12

3. Rate your general satisfaction with the lighting as modified in the test area. Enter an X in the column appropriate for each item.

	Suitable	Unsuitable
a. General aisle light	16	12
b. Flight Strip illumination	13	15
c. Map board lighting (consider the version you prefer as best)	23	3
d. PVD Keys and CUE	20	7
e. Flight Strip Printer (best alternative)	21	2
f. Shelf area of PVD	22	5
g. General working area for D man	10	17
h. General working area for A man	15	11

4. Recognizing that the brighter the general control room lighting, the more reflections will be produced, how important is it to have a high level of room light ? (check one)

a. General room light should be lower than usual 8

b. General room light should be about where it usually is 8

c. General room light should be increased 12

5. Do you think that different control room jobs can be better performed under particular light levels ? (Note your agreement or difference with each of the following statements.)

	Agree	Disagree
a. Radar controllers need a dimly lighted control room	14	14
b. Manual controllers need a low light level also	5	23
c. Assistant controllers prefer more light	21	6
d. Floor supervisors prefer more light than R-men	21	5
e. Managers prefer a control room with more light	16	8

6. Since the under the counter "knee lights" allow turning off or reducing the light on control room walls, do you find using them reduces reflections ?

	Agree	Disagree
a. With knee lights and less wall light, reflections are down	14	9

7. Map Board lighting has been modified three different ways. Which do you prefer and how do you evaluate each method?

a. The method that improves the visual situation at the PVD the most is:

The timing switch 2 Light control film 23 Map Negatives 4

	Excellent	Good	Fair	Poor	Bad
b. Using the timing switch map-board lighting is:	1	4	5	9	11
Using the light control film map-board ltg is	7	15	4	2	3
Using Negative Maps Map-board Lighting is	2	6	7	8	7

8. Flight strip bay lights have been demonstrated with louvers added to reduce the spread of light, with added light control plastic material inserted under the louvers, and with no louvers. Please indicate your choice of the best of these lights and rate each one.

a. The method of lighting strip bays that is best in my opinion is:

No louvers 2 With louvers 10 With louvers over the plastic 13

b. With no louvers, strip bay lighting is: Excellent 3 Good 6 Fair 1 Poor 7 Bad 6

With added louvers, strip bay lighting is: Excellent 1 Good 10 Fair 9 Poor 5 Bad 0

With louvers over the plastic, strip bay lighting is: Excellent 0 Good 12 Fair 5 Poor 2 Bad 4

9. Printer lamps have been screened with light control plastic material and also with gray plastic and with green plastic. Please indicate your choice as to the best of these methods of reducing excess light and rate each one.

a. The best method of reducing printer lamp intensity is:

Light control material 2 Gray filter 8 Green filter 16

b. Using the light control material, lamp intensity reduction is: Excellent 2 Good 7 Fair 13 Poor 1 Bad 1

Using gray filter, lamp intensity control is: Excellent 1 Good 10 Fair 11 Poor 1 Bad 1

Using green filter, lamp intensity control is: Excellent 3 Good 15 Fair 4 Poor 3 Bad 1

10. Printer general illumination was demonstrated with a gray and also with a green baffle added to reduce light output. Please indicate your choice of the best method to use and rate each one.

a. The best printer general illumination condition is:

Without an added baffle 2 Gray baffle 8 Green baffle 12

b. Without a baffle, printer general illumination is: Excellent 3 Good 4 Fair 6 Poor 8 Bad 0

With an added gray baffle, printer illumination is: Excellent 1 Good 11 Fair 8 Poor 1 Bad 0

With an added green baffle, printer illumination is: Excellent 2 Good 12 Fair 3 Poor 3 Bad 1

11. Evaluate the changes made at the supervisor's desk as follows:

a. The three-sided desk shield intended to help the floor controllers by blocking off a glare source is:

Excellent 2 Beneficial 19 Fair 3 Poor 2 Bad 2

b. Of the several new desk lamps demonstrated, the best from the view of the floor controllers is:

Lamp A 1 Lamp B 6 Lamp C 3 Lamp D 14 Lamp E 0 Lamp F 0

c. As a controller, which of the lamps on the floor supervisor's desk emitted the least stray light at your position:

Lamp A 2 Lamp B 1 Lamp C 0 Lamp D 11 Lamp E 0 Lamp F 0

12. Evaluate the two types of key caps demonstrated at the PVD on the ANK:

a. The best key cap is: Black letter on white 5

White letter on black 21

b. For visual comfort, the black letter on white background caps are:

Excellent 2 Good 5 Fair 8 Poor 5 Bad 3

For visual comfort, the white letter on black background caps are:

Excellent 8 Good 14 Fair 3 Poor 1 Bad 0

c. For legibility, the black letter on white background caps are:

Excellent 1 Good 8 Fair 10 Poor 5 Bad 0

For legibility, the white letter on black background caps are:

Excellent 9 Good 13 Fair 3 Poor 1 Bad 0

13. In the test area, the plenum lights have been controlled to provide an improved barance of illumination. Evaluate the importance of keeping these lights balanced:

Essential 7 Desirable 12 Unimportant 1 A distraction 1

Bad 2

14. As one attempt to improve vision at the PVD, a nylon mesh was placed over the CRT. Evaluate the utility of this mesh for the controller:

The nylon mesh is: Essential 0 Good 0 Fair 2 Poor 5 Bad 1

15. **Summarize in your own words your general reaction to the lighting changes in the test area:**

a. **The controller's visual situation is better in the test area in these ways**

Glare on PVD was reduced . . . 9

Reflections on PVD were reduced . . 4

Map Boards with film were good . 4

b. **The controller's visual situation is worse in the test area in these ways**

Bright strips vs. PVD . . 7

Too dark in test area . . 3

Glare on D side of PVD . . 2

16. **Other or different lighting changes or improvements that should be tested are as follows:**

Better strip lighting . . 3

Increase ambient lighting . 4

Improve PVD . . . 2

17. Please add any comments that you may care to make about the control room lighting test. For example, do you think the test was long enough? Was the method of illustrating the changes adequate? Were too many lighting changes demonstrated all at once, or could you sort out the different effects when answering the questionnaire? etc.

Need more tests and improvements . . . 3

Prefer a well lighted environment, ambient and at supervisor's desk . . 4

(Phase II)

QUESTIONNAIRE FOR

EVALUATION OF CONTROL ROOM LIGHTING IMPROVEMENTS

INSTRUCTIONS

In July, various lighting changes were demonstrated in Area D to reduce annoying glare and reflections. Later, several special changes, such as the adjustable background brightness on the PVD and the PVD sloped at 45°, were tried. Now Area D has a mostly standard set of lighting changes, including the balanced plenum lights, light control film or black negative maps on the overhead boards, and extended louvers below the flight strip lights.

The goals of the present evaluation are to determine:

1. Is this combination of final changes acceptable?
2. If it is acceptable, is the package of changes of significant benefit to control room personnel?
3. Are there other lighting changes that should be tested?

Date Questionnaire completed______________________________

Your highest ATC qualification____________________________

Years service at Boston Center__________

If a supervisor, check here__________

1. Rate the acceptability of the modified lighting in Area D by checking the appropriate column for each item.

		Acceptable	Not acceptable
a.	General aisle light	16	17
b.	Flight strip lighting	21	11
c.	Map board with light control filter material	22	11
d.	Black background map boards	9	24
e.	Black keycaps on PVD	25	7
f.	Flight strip printer with green filter	24	8
g.	Present level of reflections on CRT at PVD	13	18
h.	Supervisor's desk & log area	18	12

2. Please note the single aspect of control room lighting that you think has been improved so as to be the most help for the radar controllers by entering the letter (a, b, c, d, e, f, g, or h) of one of the items, above.

The most improved lighting area is listed as letter C = 16

3. Please note the single aspect of control room lighting that you think has been least improved for the radar controller.

The least improved lighting area is listed as letter B = 9

G = 8

4. Independent of your answers to the previous questions, please note the single aspect of control room lighting that still needs further improvement more than any other to help the radar man.

Most needing further improvement is the item listed as letter G = 11

B = 6

5. Is the total package of lighting changes (disregarding black maps) in Area D acceptable?

Yes 10 No 22

6. If you said "Yes" to item 5, is that package of lighting changes of significant value to the radar controller?

Yes 10 No 0

7. If you answered "No" to item 5, please select one of the following statements that most closely expresses your opinion:

a. My reason for rejecting the package is largely based on the opinion that one particular lighting aspect needs major improvement. That area is listed in item 1 as letter: G = 7 B = 4

b. My main reason for rejection is that a particular needed change has not yet been tested. That change is the following:

Want increased room light . . . 3

Want adjustable background on PVD . 3

c. Neither of above. My main reason for rejection is:

Only partial solutions, need more . . 2

8. Is the masking of bright speaker bezels helpful in reducing reflections at the PVD?

Yes 12 No 15

9. Please answer this question only if you had an opportunity to examine the single PVD that had a woven mesh over the CRT.

My evaluation is that the particular mesh used (select one of the following):

a. Improved the ability of the controller to use the display 9

b. Reduced the ability of the controller to use the display 3

c. Had no important effect 2

10. Please answer this question only if you had an opportunigy to observe the PVD that was sloped at a 45° angle.

My opinion is that using a 45° slope would have the following effect on the visual situation of the controller:

a. Would help the controller working at the PVD 3

b. Would reduce work efficiency by that controller 7

c. Would have no important effect 3

11. Has the change to the Luxor lamp over the flight strips been a worthwhile change?

Yes 18 No 8

12. Is the extended louver system with safety shield a satisfactory way to prevent some unwanted light spill over on the PVD?

Yes 22 No 11

13. While several previous questions asked the value of the lighting changes for the controllers working at the PVD, this question refers of the impact of the changes on the D-man. Please note the one statement, below, by circling its letter, that most nearly expresses your opinion:

a. The package of lighting changes in Area D helps the D-man. — 12

b. The package has no important effect on the D-man. — — 5

c. The visual situation of the D-man is made worse. — — - 11

d. None of above. My opinion is ____________________

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14. Assuming a favorable consensus is produced in this evaluation, should the results be sent to other ARTCC's with a recommendation that they consider implementing the same lighting changes that are now in Area D?

Yes 17 No 13

15. If you said "No" to item 14, would you change your answer to "Yes" if certain parts of the lighting package were dropped?

Yes 5 No 7